of 1600 fathoms, in the South Atlantic (S. lat. 46° 16′, E. long. 48° 27′), a living specimen of a magnificent shell belonging to *Cymbium*, or an allied genus, which is 6¾ inches long and 4 inches broad! I dredged other Mollusca from an inch and a half to nearly double that length in the *Porcupine* and *Valorous* expeditions. Willemöes Suhm mentions among the *Challenger* discoveries a gigantic crustacean or sea-spider from 1375 fathoms, which measured nearly two feet across the legs.

Sir Wyville Thomson gives an eloquent description of life in the deep sea, when he says that the latter "is inhabited by a fauna more rich and varied on account of the enormous extent of the area, and with the organisms in many cases apparently even more elaborately and delicately formed, and more exquisitely beautiful in their soft shades of colouring, and in the rainbow tints of their wonderful phosphorescence, than the fauna of the well-known belt of shallow water teeming with innumerable invertebrate forms which fringes the land. And the forms of these hitherto unknown living beings, and their mode of life, and their relations to other organisms whether living or extinct, and the phenomena and laws of their geographical distribution, must be worked out."

It was formerly supposed that animals could not exist at great depths because of the great pressure to which they were subjected. Mr. Moseley says[1] "the pressure exerted by the water at great depths is enormous, and almost beyond comprehension. It amounts roughly to a ton weight on the square inch for every 1000 fathoms of depth; so that, at the depth of 2500 fathoms, there is a pressure of two tons and a half per square inch of surface, which may be contrasted with the fifteen pounds per square inch pressure to which we are accustomed at the level of the sea." But it must be recollected that water is nearly incompressible, and that marine animals which are surrounded by such a fluid, and are to a certain extent filled with it, would not necessarily be inconvenienced by the superincumbent weight.

Animals from great or even from what may be considered moderate depths are always brought up dead, the cause of death being unknown. This is another problem worthy of being worked out.

The migration or distribution of marine animals throughout the open sea is quite free, and is unobstructed only by great or abrupt changes of level in the bed of the ocean, which operate as barriers. Even animals of a fixed or sedentary nature in their earliest state of growth swim on the surface, and are therefore unchecked in their onward course by any submarine barrier.

The doubt whether any life exists in the intermediate space or zone which lies between that of the surface and that of the bottom of the deep sea has now, I believe, been set at rest. The naturalists in the *Josephine* expedition believed that this intermediate zone is lifeless; and Sir Wyville Thomson seems to have been of the same opinion. The towing-net adopted by Mr. Murray in the *Challenger* expedition for such researches was to some extent successful; but Capt. Sigsbee, of the U.S. Coast-Survey steamer *Blake*, invented a cylinder or machine, called the "gravitating trap," which completely answered the purpose of collecting at any particular depth the animals which occurred there. Prof. Alexander Agassiz, in his communication to the Superintendent of the Survey made last August, and now published, records the experiments thus made, and says that they "appear to prove conclusively that the surface-fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal life between those living on the bottom, or close to it, and the surface pelagic fauna."

I am not aware that any deep-sea animals adopt or avail themselves of the same means that oceanic or land animals use for purposes of protection and concealment, chiefly by coloration or by what has been termed "mimicry." Many cases of this kind are known to occur in birds, fishes, mollusks, *Salpæ*, insects, crabs, shrimps, and worms.

None of the animals whose remains are found in geological formations older than the Pliocene or latest of the Tertiary strata have yet been detected in any exploring expedition. The late Prof. Agassiz and Sir Wyville Thomson were disappointed in their enthusiastic expectation of finding Ammonites, Belemnites, and other Old-World fossils in a living state. I have dredged Miocene fossils on the coasts of Guernsey and Portugal, the latter at considerable depths; but they were petrifactions, and must have come from some fossiliferous formation in the adjacent land, or perhaps in the sea-bed.

[1] "Notes of a Naturalist on the *Challenger*."

Sir Wyville Thomson, in his "Report of the Scientific Results of the Voyage of H.M.S. *Challenger*," has expressed his opinion as to the doctrine of evolution, that "in this, as in all cases in which it has been possible to bring the question, however remotely, to the test of observation, the character of the abyssal fauna refuses to give the least support to the theory which refers the evolution of species to extreme variation guided only by natural selection." I cannot understand how either "natural selection" or "sexual selection" can affect marine invertebrate animals, which have no occasion to struggle for their existence and have no distinction of sex.

(*To be continued.*)

THE RELATION BETWEEN ELECTRICITY AND LIGHT.[1]

EVER since the subject on which I have the honour to speak to you to-night was arranged, I have been astonished at my own audacity in proposing to deal in the course of sixty minutes with a subject so gigantic and so profound that a course of sixty lectures would be quite inadequate for its thorough and exhaustive treatment.

I must indeed confine myself carefully to some few of the typical and most salient points in the relation between electricity and light, and I must economise time by plunging at once into the middle of the matter without further preliminaries.

Now when a person is setting off to discuss the relation between electricity and light it is very natural and very proper to pull him up short with the two questions: What do you mean by electricity? and What do you mean by light? These two questions I intend to try briefly to answer. And here let me observe that in answering these fundamental questions I do not necessarily assume a fundamental ignorance on your part of these two agents, but rather the contrary; and must beg you to remember that if I repeat well-known and simple experiments before you, it is for the purpose of directing attention to their real meaning and significance, not to their obvious and superficial characteristics: in the same way that I might repeat the exceedingly familiar experiment of dropping a stone to the earth if we were going to define what we meant by gravitation.

Now then we will ask first, What is Electricity? and the simple answer must be, We don't know. Well, but this need not necessarily be depressing. If the same question were asked about Matter, or about Energy, we should have likewise to reply, No one knows.

But then the term Matter is a very general one, and so is the term Energy. They are heads, in fact, under which we classify more special phenomena.

Thus if we were asked what is sulphur, or what is selenium, we should at least be able to reply, A form of matter; and then proceed to describe its properties, *i.e.* how it affected our bodies and other bodies.

Again, to the question, What is heat? we can reply, A form of energy; and proceed to describe the peculiarities which distinguish it from other forms of energy.

But to the question, What is electricity? we have no answer pat like this. We cannot assert that it is a form of matter, neither can we deny it; on the other hand, we certainly cannot assert that it is a form of energy, and I should be disposed to deny it. It may be that electricity is an entity *per se*, just as matter is an entity *per se*.

Nevertheless I can tell you what I mean by electricity by appealing to its known behaviour.

Here is a battery, that is, an electricity pump: it will drive electricity along. Prof. Ayrton is going, I am afraid, to tell you, on the 20th of January next, that it *produces* electricity; but if he does, I hope you will remember that that is exactly what neither it nor anything else can do. It is as impossible to generate electricity in the sense I am trying to give the word, as it is to produce matter. Of course I need hardly say that Prof. Ayrton knows this perfectly well; it is merely a question of words, *i.e.* of what you understand by the word electricity.

I want you then to regard this battery and all electrical machines and batteries as kinds of electricity pumps, which drive the electricity along through the wire very much as a water-pump can drive water along pipes. While this is going on the wire manifests a whole series of properties, which are called the properties of the current.

[1] A lecture by Dr. O. J. Lodge, delivered at the London Institution o December 16, 1880.

[Here were shown an ignited platinum wire, the electric arc between two carbons, an electric machine spark, an induction-coil spark, and a vacuum tube glow. Also a large nail was magnetised by being wrapped in the current, and two helices were suspended and seen to direct and attract each other.]

To make a magnet, then, we only need a current of electricity flowing round and round in a whirl. A vortex or whirlpool of electricity is in fact a magnet; and *vice versâ*. And these whirls have the power of directing and attracting other previously existing whirls according to certain laws, called the laws of magnetism. And, moreover, they have the power of exciting fresh whirls in neighbouring conductors, and of repelling them according to the laws of diamagnetism. The theory of the actions is known; though the nature of the whirls, as of the simple stream of electricity, is at present unknown.

[Here was shown a large electro-magnet and an induction-coil vacuum discharge spinning round and round when placed in its field.]

So much for what happens when electricity is made to travel along conductors, *i.e.* when it travels along like a stream of water in a pipe, or spins round and round like a whirlpool.

But there is another set of phenomena, usually regarded as distinct, and of another order, but which are not so distinct as they appear, which manifest themselves when you join the pump to a piece of glass or any non-conductor and try to force the electricity through that. You succeed in driving some through, but the flow is no longer like that of water in an open pipe; it is as if the pipe were completely obstructed by a number of elastic partitions, or diaphragms. The water cannot move without straining and bending these diaphragms, and if you allow it, these strained partitions will recover themselves and drive the water back again. [Here was explained the process of charging a Leyden jar.] The essential thing to remember is that we may have electrical energy in two forms, the static and the kinetic; and it is therefore also possible to have the rapid alternation from one of these forms to the other, called vibration.

Now we will pass to the second question: What do you mean by light? And the first and obvious answer is, Everybody knows. And everybody that is not blind does know to a certain extent. We have a special sense-organ for appreciating light, whereas we have none for electricity. Nevertheless, we must admit that we really know very little about the intimate nature of light—very little more than about electricity. But we do know this, that light is a form of energy; and, moreover, that it is energy rapidly alternating between the static and the kinetic forms—that it is, in fact, a special kind of energy of vibration. We are absolutely certain that light is a periodic disturbance in some medium, periodic both in space and time: that is to say, the same appearances regularly recur at certain equal intervals of distance at the same time, and also present themselves at equal intervals of time at the same place; that in fact it belongs to the class of motions called by mathematicians undulatory or wave motions. The wave motion in this model (Powell's wave apparatus) results from the simple up-and-down motion popularly associated with the term *wave*. But when a mathematician calls a thing a wave he means that the disturbance is represented by a certain general type of formula, not that it is an up-and-down motion, or that it looks at all like those things on the top of the sea. The motion of the surface of the sea falls within that formula, and hence is a special variety of wave motion, and the term wave has acquired in popular use this signification and nothing else. So that when one speaks ordinarily of a wave or undulatory motion one immediately thinks of something heaving up and down, or even perhaps of something breaking on the shore. But when we assert that the form of energy called light is *undulatory*, we by no means intend to assert that anything whatever is moving up and down, or that the motion, if we could see it, would be anything at all like what we are accustomed to in the ocean. The kind of motion is unknown; we are not even sure that there is anything like motion in the ordinary sense of the word at all.

Now how much connection between electricity and light have we perceived in this glance into their natures? Not much truly. It amounts to about this: That on the one hand electrical energy may exist in either of two forms—the static form, when insulators are electrically strained by having had electricity driven partially through them (as in the Leyden jar), which strain is a form of energy because of the tendency to discharge and do work; and the kinetic form, where electricity is moving bodily along through conductors or whirling round and round inside them, which motion of electricity is a form of energy, because the conductors and whirls can attract or repel each other and thereby do work.

And, on the other hand, that light is the rapid alternation of energy from one of these forms to the other—the static form where the medium is strained, to the kinetic form when it moves. It is just conceivable then that the static form of the energy of light is *electro*-static, that is, that the medium is *electrically* strained, and that the kinetic form of the energy of light is *electro*-kinetic, that is, that the motion is not ordinary motion, but electrical motion—in fact that light is an electrical vibration, not a material one.

On November 5 last year there died at Cambridge a man in the full vigour of his faculties—such faculties as do not appear many times in a century—whose chief work has been the establishment of this very fact, the discovery of the link connecting light and electricity; and the proof—for I believe it amounts to a proof—that they are different manifestations of one and the same class of phenomena—that light is, in fact, an electro-magnetic disturbance. The premature death of James Clerk Maxwell is a loss to science which appears at present utterly irreparable, for he was engaged in researches that no other man can hope as yet adequately to grasp and follow out; but fortunately it did not occur till he had published his book on "Electricity and Magnetism," one of those immortal productions which exalt one's idea of the mind of man, and which has been mentioned by competent critics in the same breath as the "Principia" itself.

But it is not perfect like the "Principia"; much of it is rough-hewn, and requires to be thoroughly worked out. It contains numerous misprints and errata, and part of the second volume is so difficult as to be almost unintelligible. Some, in fact, consists of notes written for private use, and not intended for publication. It seems next to impossible now to mature a work silently for twenty or thirty years, as was done by Newton two and a half centuries ago. But a second edition was preparing, and much might have been improved in form if life had been spared to the illustrious author.

The main proof of the electro-magnetic theory of light is this. The rate at which light travels has been measured many times, and is pretty well known. The rate at which an electro-magnetic wave disturbance would travel if such could be generated (and Mr. Fitzgerald of Dublin thinks he has proved that it cannot be generated directly by any known electrical means) can be also determined by calculation from electrical measurements. The two velocities agree exactly. This is the great physical constant known as the ratio V, which so many physicists have been measuring, and are likely to be measuring for some time to come.

Many and brilliant as were Maxwell's discoveries, not only in electricity, but also in the theory of the nature of gases, and in molecular science generally, I cannot help thinking that if one of them is more striking and more full of future significance than the rest, it is the one I have just mentioned—the theory that light is an electrical phenomenon.

The first glimpse of this splendid generalisation was caught in 1845, five and thirty years ago, by that prince of pure experimentalists, Michael Faraday. His reasons for suspecting some connection between electricity and light are not clear to us—in fact they could not have been clear to him; but he seems to have felt a conviction that if he only tried long enough, and sent all kinds of rays of light in all possible directions across electric and magnetic fields in all sorts of media, he must ultimately hit upon something. Well, this is very nearly what he did. With a sublime patience and perseverance which remind one of the way Kepler hunted down guess after guess in a different field of research, Faraday combined electricity, or magnetism, and light in all manner of ways, and at last he was rewarded with a result. And a most out-of-the-way result it seemed. First you have to get a most powerful magnet and very strongly excite it; then you have to pierce its two poles with holes, in order that a beam of light may travel from one to the other along the lines of force; then, as ordinary light is no good, you must get a beam of plane polarised light and send it between the poles. But still no result is obtained until, finally, you interpose a piece of a rare and out-of-the-way material which Faraday had himself discovered and made, a kind of glass which contains borate of lead, and which is very heavy, or dense, and which must be perfectly annealed.

And now, when all these arrangements are completed, what is

seen is simply this, that if an analyser is arranged to stop the light and make the field quite dark before the magnet is excited, then directly the battery is connected and the magnet called into action a faint and barely perceptible brightening of the field occurs; which will disappear if the analyser be slightly rotated. [The experiment was then shown.] Now no wonder that no one understood this result. Faraday himself did not understand it at all: he seems to have thought that the magnetic lines of force were rendered luminous, or that the light was magnetised; in fact he was in a fog, and had no idea of its real significance. Nor had any one. Continental philosophers experienced some difficulty and several failures before they were able to repeat the experiment. It was in fact discovered too soon, and before the scientific world was ready to receive it, and it was reserved for Sir William Thomson briefly, but very clearly, to point out, and for Clerk Maxwell more fully to develop, its most important consequences. [The principle of the experiment was then illustrated by the aid of a mechanical model.]

This is the fundamental experiment on which Clerk Maxwell's theory of light is based; but of late years many fresh facts and relations between electricity and light have been discovered, and at the present time they are tumbling in in great numbers.

It was found by Faraday that many other transparent media besides heavy glass would show the phenomenon if placed between the poles, only in a less degree; and the very important observation that air itself exhibits the same phenomenon, though to an exceedingly small extent, has just been made by Kundt and Röntgen in Germany.

Dr. Kerr of Glasgow has extended the result to opaque bodies, and has shown that if light be passed through magnetised *iron* its plane is rotated. The film of iron must be exceedingly thin, because of its opacity, and hence, though the intrinsic rotating power of iron is undoubtedly very great, the observed rotation is exceedingly small and difficult to observe; and it is only by very remarkable patience and care and ingenuity that Dr. Kerr has obtained his result. Mr. Fitzgerald of Dublin has examined the question mathematically, and has shown that Maxwell's theory would have enabled Dr. Kerr's result to be predicted.

Another requirement of the theory is that bodies which are transparent to light must be insulators or non-conductors of electricity, and that conductors of electricity are necessarily opaque to light. Simple observation amply confirms this; metals are the best conductors, and are the most opaque bodies known. Insulators such as glass and crystals are transparent whenever they are sufficiently homogeneous, and the very remarkable researches of Prof. Graham Bell in the last few months have shown that even *ebonite*, one of the most opaque insulators to ordinary vision, is certainly transparent to some kinds of radiation, and transparent to no small degree.

[The reason why transparent bodies must insulate, and why conductors must be opaque, was here illustrated by mechanical models.]

A further consequence of the theory is that the velocity of light in a transparent medium will be affected by its electrical strain constant; in other words, that its refractive index will bear some close but not yet quite ascertained relation to its specific inductive capacity. Experiment has partially confirmed this, but the confirmation is as yet very incomplete. But there are a number of results not predicted by theory, and whose connection with the theory is not clearly made out. We have the fact that light falling on the platinum electrode of a voltameter generates a current, first observed, I think, by Sir W. R. Grove at any rate it is mentioned in his "Correlation of Forces"—extended by Becquerel and Robert Sabine to other substances, and now being extended to fluorescent and other bodies by Prof. Minchin. And finally—for I must be brief—we have the remarkable action of light on selenium. This fact was discovered accidentally by an assistant in the laboratory of Mr. Willoughby Smith, who noticed that a piece of selenium conducted electricity very much better when light was falling upon it than when it was in the dark. The light of a candle is sufficient, and instantaneously brings down the resistance to something like one-fifth of its original value.

I could show you these effects, but there is not much to see; it is an intensely interesting phenomenon, but its external manifestation is not striking—any more than Faraday's heavy glass experiment was.

This is the phenomenon which, as you know, has been utilised by Prof. Graham Bell in that most ingenious and striking invention, the photophone. By the kindness of Prof. Silvanus Thompson I have a few slides to show the principle of the invention, and Mr. Shelford Bidwell has been good enough to lend me his home-made photophone, which answers exceedingly well for short distances.

I have now trespassed long enough upon your patience, but I must just allude to what may very likely be the next striking popular discovery, and that is the transmission of light by electricity; I mean the transmission of such things as views and pictures by means of the electric wire. It has not yet been done, but it seems already theoretically possible, and it may very soon be practically accomplished.

ENDOWMENT OF RESEARCH IN BIRMINGHAM

THE President of the Birmingham Philosophical Society, Dr. Heslop, recently gave an address to the members, taking for his subject the "Scientific Situation in Birmingham." Having reviewed the various local agencies set up during the past year for the diffusion of knowledge, including the opening of Mason's Science College, he went on to say: I must now allude to the most important work undertaken by the Society, the establishment of the fund for the endowment of research. This action has received warm support in many quarters, and has in fact done more to place it in a favourable light before the country than any previous circumstances. Although the efforts made to raise this fund have been inconsiderable, yet nearly 100*l*. in annual subscriptions, of varying dates, and 900*l*. in donations have been obtained. The Council have invested 600*l*. in order to ensure the permanence of the fund. It is probable that some slight additions may be made to this sum, having the same object in view; but it is, I believe, their intention to recommend the Society to spend the whole income, howsoever derived, in annual grants to persons living in this town or neighbourhood who devote themselves wholly or in part to science research. It is an error to suppose that this fund is to be allotted either to any particular individual or specially to members of this Society. The Council are free to do what they deem best with the money intrusted to them, within the limits of the scheme agreed upon. There is another temporary limit to their powers. One eminent investigator (Dr. Gore) is allotted a certain sum for a certain period. The approval of this step evinced by those who have contributed to the fund, and by others, has been a source of satisfaction to the Council.

I wish now to remind you that the scheme in connection with this subject declares that "the Council are of opinion that this Society would be omitting a principal means of the advancement of science—the end for which all such associations exist—if it neglected the question of the endowment of research. To maintain a successful investigator in his labours, even though no results of immediate or obvious utility can be shown to spring out of them, is of interest to the community at large." It may be that you will pronounce these words to be truisms scarcely requiring formal enunciation. The fact is that though the sense of them has been repeatedly given to the public in late years, practical action has not ensued. Everybody is telling his neighbour what a good thing it would be if men endowed with an aptitude for research into the facts of nature were also endowed with the means of living during their work. The speaker and the listener go by on the other side, and no good Samaritan tenders help to the well-praised searcher after truth. Nay, Mr. Mark Pattison affirms in his late book on Milton that "the England of our day has decided against the endowment of science," and seems to think that the principle on which the decision is based may be wrong, but "is not unreasonable." But the endowment of ministers of science stands on quite another foundation from that of ministers of religion. "To assign a place with a salary," says Mr. Pattison, "is to offer a pecuniary inducement to simulate" the qualification, *i.e.* a state of grace. But in the case of science there is no question of place, and the endowment is offered, not to those who promise much, but to those who have already performed something; not to those who imagine themselves to be in the requisite spiritual state, but to those who, working for an audience, select though few, have demonstrated that they are touched by the divine fire which burns not for other men.

In the opinion of others the only practicable mode of dealing with this question is by bestowing adequate funds on teachers, and by placing them in favourable conditions for research.